S.S. PAPADOPULOS & ASSOCIATES, INC.
ENVIRONMENTAL & WATER-RESOURCE CONSULTANTS

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105
Attention: Mr. Bob Pallarino

STATE OF HAWAII
DEPARTMENT OF HEALTH
P.O. Box 3378
Honolulu, HI 96801-3378
Attention: Fenix Grange, M.S., Program Manager

Subject: Comments on Presentation Materials from the Red Hill Groundwater Modeling Working Group (GWMWG) Meeting #7 and Status of Interim Modeling as Presented Associated with Administrative Order on Consent ("AOC") Statement of Work Requirements 7.1.3 (Groundwater Flow Model Report) and 7.2.3 (Contaminant Fate and Transport Report)

Dear Mr. Pallarino and Ms. Grange:

At the request of the U.S. Environmental Protection Agency ("EPA") and Hawaii Department of Health ("DOH"), collectively the "Regulatory Agencies", I am providing comments and suggestions regarding the status and progress of activities associated with Administrative Order on Consent ("AOC") Statement of Work Requirements 7.1.3 (Groundwater Flow Model Report) and 7.2.3 (Contaminant Fate and Transport Report), emphasizing materials presented at the Red Hill Groundwater Modeling Working Group (GWMWG) Meeting #7, January 11th, 2018.

First, it is important to acknowledge the progress in recent months on site characterization, data collection, and the evaluation of those data. The Navy and its contractors have been diligent in their efforts and much good work has been completed. Any evaluation of the potential risk posed by Red Hill fuel storage must be substantiated by extensive, high-quality data and associated analyses and in this context, the progress on data collection and analysis is welcomed. These data and analyses, together with independent information from prior local studies and analogous site studies, form the basis for the conceptual site model (CSM) that will underpin subsequent modeling.

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In addition, the development of the interim groundwater flow (capture) model presented to-date is in many respects of high quality, and consistent with the AOC and the anticipated progress of model development at this time. It was particularly encouraging to be recently presented draft particle tracking output based on the current interim groundwater flow model, which illustrated how the model when further developed can help assess the zones of contribution to water supply shafts as required by the AOC, and provide a basis for the final flow and transport models.

However, based on materials presented to-date, the CSM of Red Hill that is in development by the Navy appears over-simplified in its present form and appears to omit site-specific features and processes that are likely to play an important role in evaluating the risk posed by Red Hill fuel storage to potential receptors including Halawa and Red Hill shafts. Related to this, there are at this time simplifications in the development of the groundwater model that parallel concerns expressed above and below regarding the status of the CSM. While simplifications necessitated in the early stages of CSM and model development, and embodied in interim or "screening-level" analyses, are often assumed to be *de-facto* protective, the complex conditions at Red Hill offer no assurance of conservatism via simplification. Given this, the CSM and subsequent model development and application should be inclusive rather than exclusive until data and analyses might render undesirable outcomes sufficiently improbable; and, where data are absent or site conditions unknown, more conservative (i.e., protective) assumptions should be used.

Specific areas of concern are noted below, together with suggestions to remedy these concerns. Because G.D. Beckett (AQUI-VER, Inc.) is providing the Regulatory Agencies expertise on the evaluation of Non-Aqueous Phase Liquids (NAPL), the comments below emphasize the overall CSM and its relation to the groundwater flow and contaminant fate and transport models.

1. A priority in the development of the Red Hill CSM to support predictive modeling is a comprehensive 3-D evaluation and documentation of subsurface geologic conditions, emphasizing characteristics that influence flow, transport and fate. The Navy has stated that a 3-D geologic model has been developed based, in part, on local borings and plentiful if dated barrel logs from Red Hill. When developed to support groundwater flow and contaminant transport models, such a geologic model - incorporating evaluations of unit continuity, bedding and fracture strike and dip, and so on - can be an input basis for single or multiphase numerical models. The 3-D geologic model alluded to by the Navy may be detailed (which cannot be independently confirmed), but as noted below presently the geologic underpinnings of the groundwater model are not. Although assurances have been provided by the Navy and its contractors that these type of detailed site-specific features and processes are being considered, they have not been a focus of recent Navy presentations and it is unclear how they are to be represented and incorporated into the CSM so that it can underpin groundwater flow and transport models. If such has been completed already by the Navy, it should be presented or provided for review.
2. The groundwater and NAPL models presented at the GWMWG Meeting #7 currently rest on the assumption that the complex site geologic conditions can largely be treated as an

equivalent porous media (EPM). This assumption is unlikely to be conservative (i.e., protective), and is not supported at relevant scales by the subsurface geologic data that already exist at and near Red Hill. At this stage of development, and absent data to the contrary, the Red Hill CSM should incorporate a high likelihood of high lateral continuity of features that facilitate flow and transport. Having incorporated these more conservative assumptions in the Red Hill CSM and subsequent groundwater and NAPL models, in the event that they result in potentially unacceptable impacts to receptors, any additional field characterization and data collection can focus on obtaining information to corroborate or refute these conservative assumptions.

3. In regard (2), development of the CSM appears to have emphasized some features that may be of limited significance to the evaluation of risk, while placing less emphasis on features and processes that are likely of greater significance. For example, emphasis placed on recharge from the nearby quarry may outweigh its influence on groundwater flow and contaminant transport within underlying basalts. [*During a January 12th meeting at the quarry attended by the Regulatory Agencies, information was provided suggesting that return-flow (non-consumptive use) may be substantially less than presumed.*] in anticipation of the fate and transport analyses to come, greater attention should be given to the likely impact of basalt stratigraphy on flow, transport and fate. At this stage of the AOC and development of the Red Hill CSM, it is more appropriate to assume that intervening recharge sources and saprolites are not inherently protective until data and analyses can better inform these assumptions.

4. At present, the groundwater model represents major (first-order) Hydro-Stratigraphic Units (HSUs) – e.g., differentiating basalt from saprolite from carbonates – but does not differentiate within these HSUs (in essence assuming the subsurface can be represented as an EPM). Studies from other basalt regions, however, indicate a high potential for connected flow-paths that can enhance migration distances and rates versus EPM assumptions: and, though few controlled experiments are published for conditions directly analogous to Red Hill, studies in simpler environments show heterogeneous migration even under ideal conditions. At Red Hill, the documented geology, stratigraphic exposures in the nearby quarry, and variable hydraulic gradients indicate the subsurface is more complex than the current CSM and groundwater model represent.

5. The upgradient (i.e., northeastern mountain-front) boundary condition of the groundwater flow model may exert a strong influence on flow and migration patterns, acting to enhance or perhaps over-prescribe the propensity for flow to occur *Mauka to Makai* regardless of other factors such as recharge and pumping. This boundary condition (in concert with the lateral boundaries) should be viewed with caution and evaluated via calibration-constrained sensitivity analyses. This situation may have been reflected in the water budget analysis presented at the GWMWG Meeting #7, where the assumption of low spring flow

in 2015 at time of relatively high recharge seems counterintuitive and may suggest that the assumption of constant inflow along the mountain front may be erroneous.

6. Although instructive as an introduction to and illustration of relevant concepts and terms, the NAPL evaluation presented at the GWMWG Meeting #7 appears so simplified as to have uncertain or limited future application. The calculations appear to suggest little to no potential for groundwater impact, whereas available data appear to contradict this. The current Navy NAPL evaluation requires substantial enhancement to provide further utility in the coming quantitative evaluation of risks posed to potential receptors.

7. With regard the transition from an interim capture zone model to detailed analyses of contaminant fate, transport, and associated risk: while the work presented at the GWMWG Meeting #7 is being performed in the context of interim model development in accordance with the AOC, the approach may not yet be sufficiently comprehensive to inform tank upgrade decisions or evaluate risk. Recognizing that models are imperfect representations of the world, simplifying assumptions used to-date in the development of the Red Hill CSM, groundwater flow model and NAPL assessment could lead to over-simplified fate and transport analyses. To remedy this, the Navy should present the technical approach(es) under consideration to represent the complex subsurface conditions at Red Hill in the CSM and derived predictive models. A wide range of possibilities exists, and only a couple examples are suggested here, such as:

    a. When considering zones of contribution to supply shafts, the use of advective-dispersive rather than solely advective pathline analyses can be instructive.

    b. The dual domain formulation may be suitable for initial mass-conservative transport simulations as an alternative to discretizing the flow model at the scale of connected conductive features, although the MODFLOW-USG code selected by the Navy is ideally-suited to refinement in areas of interest and structure-imitating methods could be used to represent and parameterize the basalt geology.

    Whatever approach the Navy ultimately adopts to represent greater site-specific hydrostratigraphic and transport detail, the developed models must support realistic flow, transport, fate and risk analyses. As the development of the interim model nears completion, the Navy should present an evaluation of the appropriate scale for discretizing the groundwater flow, fate and transport models to adequately represent site conditions.

Given the requirements of the AOC, the intended applications of the groundwater flow and fate and transport models to evaluate scenarios and risk, and the reliance of these analyses on a site-specific CSM, it is likely that the models will combine locally-detail and fine discretization with regionally-simplified parameterization and discretization so that sensitivity and predictive analyses can help evaluate whether there are conditions that are consistent with the data under which an unacceptable impact could occur. The CSM and derived models will over time benefit from further data collection to help confirm or refute underlying conservative assumptions

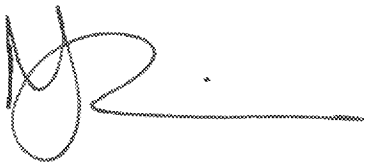
implemented to provide for protectiveness. Whether and to what extent additional characterization may be necessary is presently difficult to gage without understanding to what extent existing data have been incorporated into the Red Hill CSM and derived models. If the CSM and derived models incorporate features and processes at appropriate scales, then the necessity for and extent of any additional characterization may be informed via calibration-constrained sensitivity and predictive analysis. If the CSM and derivative models are, however, too simplified, then the models may not provide the benefit to the project that they could be capable of.

In summary, while the progress made by the Navy and its contractors is encouraging, and it is recognized that development of a comprehensive CSM and derivative predictive models must of necessity follow a systematic process of steadily incorporating site-specific complexity, at this time the Red Hill CSM appears over-simplified and it is unclear how site-specific subsurface complexity will be incorporated in a manner supportive of the pending fate and transport analyses.

Please feel free to contact me if you have any questions regarding the foregoing concerns.

Sincerely,

S. S. PAPADOPULOS & ASSOCIATES, INC.



Matthew J. Tonkin
President

Reference Materials:

(1) January 11, 2018. Groundwater Flow Model Working Group Meeting No. 7, Red Hill Bulk Fuel Storage Facility. Slide handout materials pp. 1 - 150.

(2) September 1, 2017, Revision 00. Conceptual Site Model Development and Update Plan, Investigation and Remediation of Releases and Groundwater Protection and Evaluation, Red Hill Bulk Fuel Storage Facility. Joint Base Pearl Harbor-Hickam, O'ahu, Hawai'i. Administrative Order on Consent in the Matter of Red Hill Bulk Fuel Storage Facility, EPA Docket Number RCRA 7003-R9-2015-01 and DOH Docket Number 15-UST-EA-01, Attachment A, Statement of Work Section 6.2, Section 7.1.2, Section 7.2.2, and Section 7.3.2.

(3) April 2017, Revision 00. Data Gap Analysis Report, Investigation and Remediation of Releases and Groundwater Protection and Evaluation, Red Hill Bulk Fuel Storage Facility. Joint Base Pearl Harbor-Hickam, O'ahu, Hawai'i. Administrative Order on Consent in the Matter of Red Hill Bulk Fuel Storage Facility, EPA Docket Number RCRA 7003-R9-2015-01 and DOH Docket Number 15-UST-EA-01, Attachment A, Statement of Work Section 6.2, Section 7.1.2, Section 7.2.2, and Section 7.3.2.

(4) July 2017, Final. Second Quarter 2017 - Quarterly Groundwater Monitoring Report Red Hill Bulk Fuel Storage Facility. Joint Base Pearl Harbor-Hickam, O'ahu, Hawai'i. DOH Facility ID No.: 9-102271, DOH Release ID Nos.: 990051, 010011, 020028, and 140010.

(5) Sanford, W. E., L. Niel Plummer, G. Casile, E. Busenberg, D. L. Nelms, and P. Schlosser (2017), Using dual-domain advective-transport simulation to reconcile multiple-tracer ages and estimate dual-porosity transport parameters, Water Resour. Res., 53, 5002–5016, doi:10.1002/2016WR019469.

(6) Liu, Y. and P. K. Kitanidis, 2012, Applicability of the Dual-Domain Model to Non-Aggregated Porous Media, Ground Water, 50(6): 927-934.

(7) Liu, G., C. Zheng, and S. M. Gorelick, 2007, Evaluation of the applicability of the dual-domain mass transfer model in porous media containing connected high-conductivity channels, Water Resources Res., 43, W12407, doi:10.1029/2007WR005965